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ABSTRACT

This study, an extension of previous studies, compared the views of freshmen college biology, chemistry, and physics students (N=229) with those of high school seniors (N=437), focusing on: (1) interest in different high school topics; (2) nature of high school laboratory experiences; (3) use of innovative instructional strategies in high school; (4) attitudes toward components of the matriculation examination; (5) suggestions regarding changes in high school science studies; (6) perceptions (college) and expectations (high school) of the contributions of high school experiences to studies in college; (7) relationships between nature of high school experiences and perceived help in college studies; and (8) relationship between self-reported perceptions and actual levels of retention of knowledge and achievements in college biology. Results show, in general, a high level of agreement between responses of high school and university students. High school biology came out as significantly more inquiry-oriented, incorporating more laboratory work and perceived as more helpful than either chemistry or physics in the study of the perspective science in the university. It was demonstrated that the nature of high school experience does exert significant effects on the learning of and achievement in science at the university. (Author/SK)

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CURRICULUM EVALUATION BY ITS CONSUMERS: THE ISRAEL HIGH SCHOOL SCIENCE CASE

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Abstract

Information on the nature of high school science (biology, physics, chemistry) studies and their conceived help to the study of science at the university was obtained from two independent sources, namely 12th grade high school students and first year university students. High school experiences were also related to knowledge of science upon entering the university as well as to the actual achievement in first year university science courses. Results show, in general, a high level of agreement between the responses of high school and university students. The high school biology came out as significantly more inquiry oriented, incorporating more laboratory work and perceived as more helpful than either chemistry or physics in the study of the perspective science in the university. It was demonstrated that the nature of high school experience does exert significant effects on the learning of and achievement in science at the university.

Introduction

Considerable improvements have taken place in the last two decades in science teaching at the high school level. Yet many college professors still contend that their courses will be what they are regardless of their students' high school background (Adams, 1952; Montean et al., 1963; Rozolis, 1967; Tamir, 1977). A number of studies in recent years revealed that high school preparation does play an important role in college studies. It was found that in general the study of a specific science discipline in high school did result in higher achievement in college (e.g., Tamir, 1969; Novak et al., 1971).

However, the nature of the positive contribution of high school science to learning and achievement in the universities has not been studied until very recently. In one study students at the end of their first year in a big mid-Western university in the U.S. were asked to take a retrospective view and identify weakness and advantages in their high school program. Three major conclusions of that study were:

1. The major determinant of the usefulness of a high school course appears to be its potential contribution to success in college studies.
2. Taking specific science and maths courses is directly related to the level of preparedness for college.
3. Not only the number of courses but also their quality and nature make a difference. More rigorous, more inquiry oriented as well as courses which cover more subject matter appear to have a distinct advantage over watered down easy to pass courses (Gallagher and Tamir, 1980).

In two similar retrospective studies of the relationship between high school preparation and college biology in Israel similar findings were reported (Tamir et al 1980; Tamir, Amir 1981b).

specific learning experiences. For example, studying biology in high school was found to be most helpful in understanding and retention of new material presented in the lectures in college. As to the study in university laboratories, the most helpful high school experience was that which has consisted of the student's exposure to the "new" curriculum in an academic high school where he has specialized in biology with at least two hours per week in inquiry oriented laboratories (Tamir et al., 1980).

Additionally, specializing in high school biology and studying an inquiry oriented curriculum such as the Israel BSCS Adaptation, resulted in substantial advantages for the study of college biology. These advantages were reflected by perceiving the college biology course as less difficult as well as by performing considerably better in all achievement measures employed in the college course (Tamir and Amir, 1981a).

In a recent study Tamir & Amir (1981b) compared the views of biology majors to those of physics and chemistry majors in Israel. They found that while there were differences between biologists, chemists and physicists similar mechanisms pertaining to the relationships between high school and college studies appear to exist. Following are the major findings:

1. On the average high school experiences were conceived to be of more benefit to the learning and retention of new material presented in lectures than to other modes of learning in college.
2. With regard to the laboratory, more laboratory lessons in high school and more inquiry laboratories appear to be more desirable and to lead to greater help, higher satisfaction, higher level of expectations and higher achievemen in college.

3. Students who had specialized in their science major while in high school, have on the average distinct superiority over their non-specializing counterparts, regardless of whether they major in biology, chemistry and physics.
4. While the differences are not great, biologists are, on the average, more satisfied in their high school biology studies than either physicists or chemists in their respective disciplines. They are also more content with and more interested in their matriculation examination than chemists or physicists.
5. All the respondents agree that better integration and coordination between hi school and college studies is necessary. A specially strong plea to the university professors to build on high school studies was mady by physics majors, reflecting, perhaps the sequential nature of physics.

Purpose of Study

The present study is an extension of the previous studies. It aims at comparing the views of biology, chemistry and physics students in their freshmen year in college with those of their high school counterparts, namely biology, chemistry and physics majors in their senior year in high school. More specifically, self-reports of the groups will be studied on the following:

1. Their interest in different topics in high school.
2. The nature of their high school laboratory experiences.
3. The use of innovative instructional strategies in high school science classes
4. Their attitudes toward various components of the matriculation examination.
5. Their suggestions regarding desirable changes in high school science studies.
6. Their perceptions (college) and expectations (high school) of the contributio of their high school experiences to the studies in college.

7. The relationships between nature of high school experiences and the perceived help in college studies.

In addition the relationship between the self reported perceptions on the one hand and actual levels of retention of knowledge and achievements in college biology will also be reported.

The data provide an unusual kind of assessment of high school science programs, their nature and their contribution to the study of science in college.

The comparison of similar data obtained from different independent sources may be regarded as independent replications which lend special credibility to the validity of the findings.

Method

Sample

The college sample consisted of most of the first year science students at the Hebrew University of Jerusalem in the year 1979-1980. Ninety were biology majors, 97 chemistry majors and 42 physics majors.

Of the biology majors 71% were girls. 60% had fathers with higher education and 40% had mothers with higher education. 88% studied in academic, 8% in comprehensive and 4% in agricultural high schools. 76% studies the Israel BSCS daptation. 70% took the matriculation examination in biology, 14% in physics and math and the rest in various other subjects (including students who completed their high school abroad).

Of the chemistry majors 47% were girls, 40% had fathers with higher education and 30% had mothers with higher education. 71% studies in academic, 8% in comprehensive, 6% in vocational, 9% in agricultural and 5% in kubbutz high schools. 27% studies the new chemistry curriculum. 41% took their matriculation examination in chemistry, 26% in biology, 7% in physics and the rest in various other subjects.

Of the physics majors 85% were boys, 60% had fathers with higher education and 40% had mothers with higher education. 56% studied in academic, 18% in vocational, 10% in agricultural and 15% in kibbutz high schools. 38% studied the new physics curriculum. 74% took their matriculation examination in physics, 5% in chemistry, 5% in biology and the rest in various other subjects.

The following two interesting observations are noteworth: Firstly, while three quarters of the biology majors had followed a new inquiry oriented curriculum (The Israel BSCS Adaptation) most chemistry and physics students had followed traditional programs. This is a reflection of the slower diffusion of the inquiry oriented physics and chemistry programs in Israeli high schools. Secondly, while close to three quarters of the physics and biology majors had specialized in their respective disciplines in high schools, less than half of the chemistry majors had done so. This implies that, on the average, high school preparation for college studies in chemistry is not as broad as that in physics and in biology.

It should be noted that most high school graduates spend several years in military service. Hence, their responses in 1979-80 pertain to their high school experiences in the mid-seventies.

The high school sample consisted of 437 12th grade students in the year 1980, of whom 255 majored in biology, 125 in physics and 57 in chemistry. By majors we refer to students who continue to study a particular science in 10th, 11th and 12th grade and who, by and large, take the matriculation examination in that

particular science.

The biology majors studied in twelve different schools distributed all over the country. 57% were girls, 53% had fathers with higher education and 40% had mothers with higher education. All the students studied the Israel BSCS Adaptation program.

The chemistry majors studied in two of the above mentioned twelve schools. 50% were girls, 72% had fathers with higher education, and 52% mothers with higher education. All of them studied the "new" inquiry oriented chemistry program. (Note the difference here between them and the college sample most of whom studied "traditional" chemistry).

The physics majors studied in six of the above mentioned twelve schools. Only 17% were girls, 63% had fathers with higher education, and 51% had mothers with higher education. All of them studied "traditional" physics (while 38% of the college sample had studied "new" physics).

In spite of a mean age difference of about four years the similarities between the college and high school samples are striking. Indeed two thirds of the high school samples indicated that they intend to continue their science studies in college.

Instruments, data collection and analysis

A special questionnaire was designed in order to procure the views and opinions of the students about various aspects of their high school science programs such as their degree of interest in different topics, the role of the laboratory, the extent to which innovative instructional approaches were used, the extent to which their high school science studies taught them to learn by themselves, their attitudes to various components of their matriculation

examination, the level of importance they assign to different suggestions to improve the teaching of science in high school, their interest in broadening their scientific knowledge and their expectations as to the extent to which their high school studies will help them in their study of science in college.

Many of the items were identical to those used by Tamir and Amir (1981, a+b). Certain items such as those dealing with interest in specific topics, or those dealing with different components of the matriculation examination were, by necessity, different for biology, chemistry and physics. The whole questionnaire used a Likert type 4 levels scale in which 1 = very little or very rare; 2 = little or rare; 3 = much or frequent and 4 = very much or very frequent.

The data were analyzed by computer programs yielding frequency distributions as well as mean scores and standard deviations. It is realized that the scales are ordinal and therefore frequency counts were made and are partially reported. At the same time, however, in order to save space we report mean scores and standard deviations which provide a rough and easy to grasp estimate of the results. Further analysis of the data involved the use of parametric statistics such as analysis of variance and t tests. The decision to use parametric statistics with the ordinal scales is based on Abelson and Tuckey (1959) as well as on Labovitz (1970) who argues that interval statistics may be applied to any ordinal variable since "although some small error may accompany the treatment of ordinal variables as interval, this is offset by the use of more powerful, more sensitive, better developed, and more clearly interpretable statistics with known sample error" (p. 515).

Results and Interpretation

Interest in different topics in high school

The topics which appear in Tables I-III were taken from the current syllabi in Israeli high schools. Syllabi in Israel are prescribed by the Ministry of Education and Culture, although schoos and teachers have at least some flexibility in emphasizing certain topics less than others. In physics certain topics such as dynamics and kinematics constitute a core curriculum while others such as electrochemistry, heat and special theory of relativity are electives.

Insert Tables I-III about here

It may be seen that on the average the level of interest expressed by the two samples of biologists is higher than that of either chemists or physicists. The lowest level of interest is exhibited by chemists, especially by the university sample most of whom had studied "traditional" chemistry in high school. The higher level of interest of university compared with high school biologists ($t = 4.72$, $p > 0.01$) may be explained by the fact that a third of the high school sample represented students who would not continue their study of biology in college, probably because they are less interested in biology and may have decided to major in it because of various reasons, by default. This explanation is supported by the general finding that in all high school samples the range of the mean ratings is wider and extends substantially toward the lower levels of interest (a difference of more than a half standard deviation may be observed between the mean rating scores of university and high school samples in several items in the bottom of the list of the topics in each table). The difference in levels of interest between the two samples are

especially conspinous for biologists and chemists in specific topics such as anatomy, bacteriology, biochemistry, morphology, radioactivity, special relativity theory and particulate structure of mathes. Perhaps the university students are more aware of the potential of these topics. Nevertheless one should consider the possibility that there topics are less interesting to those students who do not aspire to continue their study of science in college. In certain topics in chemistry i.e. chemical families or chemical industry in Israel, an opposite trend appears: a higher level of interest was expressed by the high school sample. Taking into consideration that the university sample studied "traditional" chemistry, this may be an indication that these topics as taught within the framework of the "new" chemistry are so much more interesting that even the less selective high school sample was much more interested in studying them.

The more general and perhaps the most important result in Table I-III is the great similarity in the relative levels of interest in different topics expressed by both the high school and the university samples.

For example let us take applications of biology, chemistry of Israeli rocks and chemical industry in Israel. These topics emphasize application of science and occupy a very low position as far as the level of students' interest is concerned. Perhaps the reason is that the study of these hopics does not contribute to the study of biology or chemistry in college. Topics such as the human body, genetics organic chemistry, atom structure, dynamics and kinematica are not only inherently interesting but perhaps are conceived as more essential to the understanding of the structure of the respective disciplines. A deeper insight into the relative levels of interest reveals some interesting regularities. For example, in biology, one may look at the different topics with three dimensions in mind: Regarding types of organisms one may observe a low level of interest in plante and microorganisms as opposed to a high level of interest in animals and in humans.

These results are in full agreement with those obtained in previous studies (e.g. Tamir & Jungwirth, 1974). As far as the different fields of biology are concerned, lowest is the interest in morphology, somewhat higher in biochemistry and anatomy, even stronger in physiology and ecology and strongest in genetics and human biology. As to the learning process, a very lwo interest is associated with applications of biology, while laboratory and outdoors studies rank high in interest.

In addition to the differences among the different science disciplines, other high school background variables also appear to influence the level of interest in studying science. Thus, for example biologists whose fathers were academics or professionals had reported significantly higher level of interest in sdudying biology than their counterparts whose fathers were clerks or non-professional workers. Physicists who had specialized in physics, chemists who had specialized in chemistry and biologists who had specialized in biology, all reported a higher level of interest than their non-specializing counterparts in studying their respective disciplines in high school. Similarly, physicists and biologists who had had more than two weekly laboratory lessons in high school also reported a higher level of interest than their counterparts who had had less than two weekly laboratory lessons.

It may be concluded that the nature of study experiences is closely related to the level of interest in studying a specific science discipline.

The nature of the laboratory experiences

Two types of laboratories were defined in the questionnaire as follows: "In the confirmatory laboratory the principles, phenomena and answers are given and the role of the laboratory work is to demostrate and confirm them. (On the other hand) in the inquiry laboratory students are engaged in investigation and in solving problems the answer for which they have to find by themselves".

Table IV presents responses about various aspects related to learning in the laboratory in high school.

Insert Table IV about here

It may be seen that compared with physics and chemistry, students in biology had been engaged considerably more in laboratory work than their chemistry and physics counterparts.

However, the more significant difference relates to the nature of the laboratory experiences. While 92% of the biologists in the high school sample report that at least half of their laboratories were inquiry oriented, only 56% of the chmists and 22% of the physics high school sample report on similar experiences. The figures for the college samples are 48%, 43% and 27% respectively. The results indicate that in both 1980 and the mid seventies most physics students had predominantly confirmatory laboratory experiences. For chemists about half of the students had inquiry oriented laboratoris with a significant difference in favor of the high school sample who studied the "new" curriculum. The difference between the two biology samples reflects the fact that all the students in the high school sample studied the "new" inquiry oriented curriculum.

As to the desirable inquiry/confirmatory ratio, biologists appear to be most favorable towards inquiry, with the high school sample rejecting altogether the idea of having predominantly confirmatory laboratories. A similar position is taken by the chemistry high school sample, who like their biology counterparts studied a "new" inquiry oriented curriculum. The chemistry college sample, on the other hand, appears most reluctant to advocate inquiry laboratories, probably as a result of studying traditional chemistry in high school and perhaps due to lack of knowledge what inquiry

oriented laboratories really are. Indeed, when chemists and biologists who had studied the "new" curricula were compared with those that had studied "traditional" programs, the "new" students were found to have studied considerably more inquiry oriented laboratories.

Interestingly 80% of the college physicists, in spite of their "traditional" high school experiences, still prefer more inquiry oriented laboratories. Perhaps this is an indication of their dissatisfaction from their confirmatory laboratory experiences. This inference is supported by the relatively high percentage of physicists who prefered recitations over laboratory lessons in high school.

Innovative instructional strategies

Only the high school samples responded to this part of the questionaire. Table V presents the results.

Insert Table V about here

The data in Table V show that none of the innovative strategies is used widely. Yet, while for physics and chemistry the employment of these approaches ranges between "not at all" and "some", for the biologists a medium level of use is reported for three strategies, namely, research studies, analysis of research papers and discovery learning. As to outdoors field studies, although little use is reported by the biologists, nevertheless it is used by biologists considerably more than by either physicists or chemists. The historical approach which has been declared as one of the cornerstones of teaching science as enquiry (Schwab, 1963, p. 41), is hardly used in teaching science in Israeli high schools.

Attitudes towards various components of the matriculation examination

The matriculation examination reflects more than any other means the objectives and emphases of the different science curricula as conceived by students and teachers. This is so since naturally both teachers and students invest their efforts and activities to attain successful performance in these examinations. Hence it is reasonable to assume that the attitudes of students toward different components of the matriculation examination are a valid measure of the important they assign to different objectives of the curriculum.

The nature of the different matriculation examinations is briefly described below. In most science programs the students take a paper and pencil test as well as a practical test.

The paper and pencil test in biology consists of three parts. Part 1 contains multiple choice items. Part 2 presents situation problems which require interpretation of tables and graphs and explanation of the data based on application of biological principles. Part 3, presents a piece of research paper which requires analysis and interpretation as well as continuation of the research through the design of a new experiment. The physics test consists of interpretation of graphs explaining phenomena, qualitative and quantitative calculations, planning an experiment and predicting its results. The chemistry test includes two parts: Part 1 consists of multiple choice items while Part 2 requires interpretation of tables and graphs, calculations, explanations of phenomena and prediction of experimental results or of properties of different substances.

The practical examination in biology consists of three parts. Part 1 requires the student to design and perform a novel experiment to solve an unfamiliar problem. Students following the traditional curriculum perform a familiar experiment instead. Part 2 is an oral examination on plants and animals.

Part 3 requires the students to identify organisms with a taxonomical key. The practical examination in physics requires the performance of a familiar experiment as well as skills in using laboratory instruments.

There is no practical examination in the new chemistry curriculum. The traditional program requires the student to identify ions and salts and to explain why they did what they did.

Table VI presents the views of students on the importance of various aspects and components of the matriculation examinations. Some of the students did not respond to this part of the questionnaire, either because they had not taken the exam or because they had not been able to recall the details. The high school sample did not respond to the first four items in Table VI because, at the time, they had not taken the matriculation examination and, therefore, were not ready to make the required judgements. There are relatively few responses of the chemistry high school sample, hence these data should be considered as tentative, especially where they are in disagreement with those obtained from the college sample.

Insert Table VI about here

The results in Table VI reveal a high level of agreement between the two biology samples.

The results indicate that for the biologists the matriculation examination was more interesting, they appreciated as important all parts of the paper and pencil test and that part of the practical examination which required to design and perform an experiment to solve an unfamiliar problem. On the other hand, performing a familiar experiment, the oral examination and the identification of organisms with the aid of a key received only mediocre rating.

The chemistry examination although reflecting imporatant objectives was conceived as not interesting, requiring memorization of facts and not allowing for demonstrating the attainment of important learnings. It appears as if in general the physicists and biologists were more satisfied with their examinations than the chemists. It is noteworthy that both physicists and chemists did not appreciate quantitative calculations as much as qualitative calculations.

The main difference between the biology and physics high school samples relates to the importance of inquiry skills. The physicists assign a very high rating to routine procedures such as performing a familiar experiment or demonstrating skill in using instruments, and at the same time do not conceive as very important skills such as interpretation of graphs and tables, or planning experiments. The biologists, on the other hand take the opposite position, giving a very high premium to solving unfamiliar problems, to planning experiments and to the interpretation of graphs and tables. It is very interesting to note that when physicists reach the university they realize how much more important are inquiry skills, compared with practicing routine procedures, and they exhibit views very similar to those of the biologists. The correspondence between the views of biologists, physicists and chemists at the college level with that of the high school biologists, together with the specific results lead to the conclusion that, at least as far as inquiry skills are concerned, the biology program as reflected in the matriculation examination offers superior preparation for college studies.

Improving science teaching in high school

The importance assigned to different suggestions to improve the teaching of science may be regarded as an indicator of students' preferences of specific learning objectives and instructional strategies. Certainly they should be

considered as an important data source for future revisions of science curricula. Table VII presents the mean responses related to the three subject matter areas.

Insert Table VII about here

It may be observed that there are only a few differences among biologists, physicists and chemists of both high school and college samples. All the students would have liked to study from up-to-date texts, obtain up-to-date knowledge through a variety of up-to-date and coordinated instructional strategies, and have more active learning experiences such as small group and inquiry oriented labs.

If we take 2.5 (the mean point on the 4 points scale) as a outing point we may conclude that by and large students are satisfied with the number of hours devoted to laboratory work as well as with the broadness and deepness of subject matter coverage. Perhaps there may be a weak trend toward the study of less topics in more depth, especially in the college chemistry sample. Whether the call for recruiting younger teachers expressed by the physics and chemistry college samples is still valid may require further investigation. That very few young physics and chemistry graduates choose teaching as a profession is a well known problem in Israel as well as in many other countries. The plea of students for improvements should <u>not</u> be interpreted to mean that science teaching is poor. In fact, science teaching has improved substantially in the last ten years, especially in biology. Nevertheless, there is always room for more improvements. For example, some of the biology texts in use are more than ten years old. Even though they may have been uptodate in the mid sixties, they certainly deserve updating in 1980.

High school contribution to the studies in the university

Table VIII presents the responses to the question: "To what extent would (or did) the study of science (biology or chemistry or physics) in high school help you in studying that science in the university?"

Insert Table VIII about here

The relatively high standard deviations (as well as the wide distribution of frequency counts which are not reported in order to save space) show that different students feel differently about the extent to which they were or would be helped by their high school experiences. This result could have been expected, considering the differences among schools as well as among students. Bearing this in mind, it is striking to find out that, on the average, there are hardly any differences between biologists, chemists and physicists in the college samples. For all of them high school experiences appear to have helped more in lecture than in the laboratory. Most valued was the help of prior knowledge to the learning, understanding and retention of new material presented in lectures.

In general the expectations of the high school samples are substantially higher than the perceptions of the college samples. There are at least two plausible interpretations. One is that as students reach college they find out that the demands are different and that they have forgotten many of the details that they studied in high school. Somehow what has precipitated helps in the learning of new related materials, but not so much in the employment of sepcific skills (See Ausubel, 1963, p. 94).

An alternative explanation may refer to the lapse of several years between the high school and the college samples' experiences. Perhaps by 1980 those students who study inquiry oriented programs, especially the biologists, are indeed better prepared for individual learning from different sources, are indeed more self reliant and are indeed better prepared to understand research. It would be interesting to follow these students and find out how they actually behave when they reach college. Some support for the second interpretation is provided by the fact that high school physicists who continued to study "traditional" physics express the weakest expectations regarding the acquisition of self learning skills while the biologists whose inquiry oriented curriculum emphasizes these skills indeed exhibit the strongest expectations regarding their potential help in college.

That the nature of high school experience indeed plays an important role may be seen in the data presented in Table IX. For the purpose of brevity the four items related to laboratory on the one hand, and the four items related to the lecture on the other hand (See Table XVIII)were pooled together to become the two dependent variables in Table IX. The independant variables are listed as high school variables.

Insert Table IX about here

It may be seen that considerably greater help is reported by students who major in the university in the same discipline in which they majored in high school, who studied a "new" high school curriculum, who had more than two weekly laboratory lessons and who had more inquiry oriented laboratory experiences.

52 out of the 90 university biologists in our study had participated in another study (Tamir and Amir, 1981a)in which their knowledge and achievement in biology were assessed. Self reported perceptions of what concepts and skills had been studies in high school (Prior Study) as well as perceived levels of knowledge and understanding of this concepts and skills (Knowledge) while entering the university were measured by a specially designed instrument designated as KPSI (Knowledge and Prior Study Inventory). As well, their achievement in their first year college biology course was measured by the regular course examinations. It is of special interest to the present study to examine the relationship between high school related variables and academic achievement. Hence, even though we only have relevant data pertaining to a subsample of biologists, we decided to present them in Table X.

Insert Table X about here

The data in Table X reveal a number of positive relationships. It should be emphasized that these relationships exist in spite of the lapse of at least three years between high school graduation and entrance to the university due to military service. Thus, for example, students who perceived their high school studies as helpful to their study in college had indeed studied more concepts and skills, indeed had more knowledge of concepts and skills upon entering the university and indeed achieved better in college biology. Since the college biology course was focusing on bacteriology and molecular biology, no wonder that those who had been more interested in these topics in high school also knew more about them at entry and achieved better in the course .

High school versus college students

The present study consists of three college samples and three high school samples. Tamir, Amir (1981b) have already compared the responses of the three college samples. In this study the focus is on the comparison between the views of high school and college samples. We have already alluded to various similaritis and differences in previous sections. However, in order to facilitate the comparison, mean scores of subsets of items dealing with specific aspects were calculated and the statistical significance of the differences was tested by t tests (see Table XI).

Insert Table XI about here

The data in Table XI show that with regard to certain aspects such as the importance of different components of the matriculation examinations, or the expectations and suggestions related to science studies in college, there is full agreement between high schcol and college samples. With regard to interest in different topics studied in high school, the biology college sample reveals a higher level of interest and a similar trend may be observed in the physics samples. We explained these trends by the more selective nature of the college samples: naturally only those who are more interested in high school science, continue their studies of science in college. The lack of differences between the chemistry samples is explained by the fact that all high school students studied the "new" curriculum which is, apparently, more interesting than the traditional one even for students who do not intend to study chemistry in college.

When we turn to the other items in Table XI we find a substantial difference, especially between the expectations of the high school sample and the perceptions of the college samples. Possible explanations for these differences have already been discussed.

Discussion and conclusions

The findings indicate that high school preparation in science has significant effects on various aspects related to the study of science in the university. It appears that there are at least three mechanisms of effect in operation:

a) The nature of high school studies affects the students while they are still in high school, For example more inquiry oriented experiences and more time devoted to laboratory work tend to develop more positive attitudes and a higher level of interest in the study of science in high school.

b) The nature of the curriculum as well as that of the learning experiences in high school effect the amount of knowledge gained as well as the meaningfulness and retention of this knowledge.

c) The combination of affective variables, such as interest and confidence based on past experience, with cognitive variables such as prior knowledge of concepts and skills has a considerable effect on the way students perceive their science studies in the university, on their preferences regarding these studies, on their study skills, on their expectations and on their achievement.

A unique feature of the design of this study is the inclusion of three high school and three college samples. This design allows for a number of comparisons each of which helps to put the specific results in perspective.

For example, the three last items in Table XI reveal a high level of agreement among disciplines and within each discipline, so that it is safe to conclude that college bound science students in Israel rate their matriculation examination as reflecting important objectives, believe that a high level of coordination between high school and college studies is important and have high expectations from their college studies in terms of aquiring knowledge and study skills. As the same time, however, detected differences permit statements such as: Expectations of high school students regarding the help of their high school science studies to their college studies are considerably higher than the perceived help reported by college students, in biology, chemistry and physics. In spite of this general trend significant differences exist between biology on the one hand and physics or chemistry on the other hand. Both expectations of high school students and actual perceptions of college students regarding help, reveal considerable superiority to the biologists. Hence, it may be concluded that high school preparation in biology is more adequate than that of either chemistry or biology. What are the features of high school biology that make the difference? The results imply that these features include: a) more interesting topics; b) more laboratory work which is characterized by a higher level of inquiry; c) more innovative instructional strategies such as students' research studies, discovery learning, analysis of research papers and outdoors field studies; d) more interesting matriculation examination which offers real challenge such as solving unfamiliar problem in the laboratory; e) more opportunities to develop study skills and aquire that kind of knowledge which would be helpful in the study of biology in college. The results in Tables IX and X show that at least some of the biologists expectations and perceptions are indeed actualized when students reach college. Those who are better prepared, indeed know more, achieve better

and look back with more appreciation to their high school experiences.

Another important conclusion should also be mentioned. All the way, in different parts of the questionnaire and in different items we find that students appreciate variation and rishness in study experiences. This apperciation is especially expressed in the responses regarding desired improvements. It may be concluded that a study program which gives balanced inquiry oriented and expository learning experiences is most desirable to students and at the same time offers the most adequate preparation for college science studies.

Finally, thr results provide interesting information about the nature of science programs in Israeli high schools. Physics teaching comes out as most traditional, especially with regard to laboratory work. The "new" chemistry program reveals a number of advantages in terms of students interests, learning in the laboratory and providing inquiry experiences. The biology program occupies top position in terms of providing inquiry experiences and in many other aspects which have already been described. Since we are dealing with the same educational system, even with the same schools, and considering that the sociocultural status of the chemistry and physics students are even higher than those of the biology students (See description of samples), the explanation for the more positive results pertaining to the biology students, must be the nature of their curriculum and of their classroom experiences. Those responsible for chemistry and especially for physics teaching, are well advised to examine the ways and means used by the biologists in designing and implementing their program (e.g. Dreyfus & Tamir, 1979). All of those responsible for science teaching both in high school and at the university, including biologists, are advised to examine carefully the detailed results of the present study, so that they would be able to take adequate steps to improve science teaching in high school as well as the bridges between high school and college science.

Notes

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Table I

Interest in different topics in high school biology

Topic	High xchool N = 255 %High*	$\bar{X}$	S.D.	University N = 90 %High*	$\bar{X}$	S.D.
Human body	91	3.58	.69	93	3.67	.58
Genetics	84	3.45	.79	90	3.60	.71
Zoology	85	3.30	.75	85	3.33	.77
Field trips	80	3.25	.94	91	3.46	.78
Animal behavior	80	3.19	.88	83	3.40	.90
Evolution	74	3.14	.89	86	3.43	.76
Laboratory Work	76	3.08	.90	75	3.20	.78
Ecology	70	3.00	.94	63	2.66	1.05
Physiology	71	2.99	.94	80	3.53	.68
Botany	73	2.95	.82	79	2.98	.91
Anatomy	57	2.69	.98	79	3.21	.84
Bacteriology	57	2.66	.98	81	3.11	.78
Biochemistry	54	2.62	1.03	78	3.17	.84
Applications of biology	52	2.52	1.10	61	2.66	.93
Morphology	49	2.95	.97	66	2.80	.82
Total average		2.99	.45		3.21	.35

*%High presents the percentage of students who selected ranks 3 or 4.

Table II

Interest in different topics in high school chemistry

Topic	High school N = 57			University N = 100		
	%High*	$\bar{X}$	S.D.	%High*	$\bar{X}$	S.D.
Organic chemistry	86	3.34	.77	73	3.07	1.13
Atom structure	82	3.28	.75	91	3.45	.72
Chemical bonds	79	3.14	.88	76	3.10	.92
Acids and basis	75	2.95	1.01	70	2.89	.85
Chemical families	69	2.93	.91	58	2.65	.96
Periodic table	66	2.89	.84	77	3.04	.90
Oxidation - reduction	63	2.80	.94	63	2.74	.94
Energy in chemical reactions	57	2.68	.90	59	2.62	1.00
Chemical thermodynamics	57	2.64	1.06	49	2.41	.97
Nuclear chemistry	50	2.50	1.22	63	2.77	1.15
Polymers and proteins	38	2.40	1.21	57	2.68	1.15
Chemical industry in Israel	42	2.28	.98	25	1.81	.99
Free energy and entropy	35	1.88	1.14	28	1.95	1.09
Kinetics - reaction velocity	20	1.73	.94	37	2.15	1.05
Chemistry of Israeli rocks	9	1.33	.66	25	1.75	.98
Total average		2.76	.57		2.65	.60

* % High presents the percentage of students who selected ranks 3 or 4.

Table III

Intest in different topics in high school physics

Topic	High school N = 125			University N = 42		
	%High*	$\bar{X}$	S.D.	%High*	$\bar{X}$	S.D.
Dynamics	83	3.24	.83	85	3.26	1.07
Kinematics	82	3.19	.83	85	3.15	.99
Electromagnetism	78	3.11	.93	79	3.05	.94
Electrons and atom structure	70	3.02	1.08	95	3.61	.68
Altermate current cycles	72	2.98	1.00	75	2.69	1.24
Electrostatics	73	2.96	.86	84	3.10	.85
Statics	73	2.92	.89	73	2.89	1.05
Electrodunamics	68	2.89	1.01	76	2.95	.92
Liquids and gases	63	2.82	1.03	67	2.68	.88
Mechanics of rigid bodies	64	2.77	1.04	67	2.67	1.12
Wave theory	61	2.72	1.06	71	2.88	1.20
Radioactivity	58	2.71	1.16	87	3.35	.79
Electrochemistry	54	2.57	1.03	61	2.58	.92
Geometric light theory	56	2.57	1.06	72	2.86	.98
Heat	53	2.55	1.06	64	2.67	.86
Special Relativity Theory	45	2.33	1.27	75	3.08	1.10
Particulate structure of matter	39	2.22	1.01	67	2.85	.99
Total Average		2.82	.61		2.98	.57

* % High presents the percentage of students who selected ranks 3 or 4.

Table IV

Distribution of responses related to different aspects of high school science laboratorie
(in percents)

The Aspect	Biologists		Chemists		Physicists	
	High school N = 255	College N = 90	High school N = 57	College N = 100	High school N = 125	Colleg N = 41
Number of weekly lab lessons						
less than two	8	21	47	45	42	53
two or more	92	79	53	55	58	47
Nature of laboratory lessons						
most are confirmatory	8	52	44	57	78	73
about half are confirmatory	32	34	42	32	20	24
most are inquiry	60	14	14	11	2	3
The desirable ratio						
most confirmatory	3	32	7	50	39	21
half confirmatory	24	52	29	43	40	46
most or all inquiry	73	17	64	7	21	33
What was prefered						
recitations over labs	25	36	29	28	39	62
recitations and labs equally	48	50	39	48	41	27
labs over recitations	27	14	32	24	20	11

Table V

Occurance of innovative instructional strategies in high school science classes

Instructional Strategy	Biologists N = 255 X	S.D.	Chemists N = 57 X	S.D.	Physicists N = 125 X	S.D.	F df = 2,434	Duncan range test t 1:2	1:3	2:3
Doing research studies	2.63	.91	2.00	.76	1.71	.74	45.76***	*	*	*
Discovery learning	2.42	.80	2.18	.75	1.80	.69	23.75***	*	*	*
Analysis of research papers	2.58	1.02	1.49	.63	1.46	.62	76.55***		*	*
Outdoors field studies	2.02	.85	1.30	.50	1.39	.60	35.92***		*	*
Historical approach	1.66	.78	1.61	.67	1.46	.58	2.98**		*	

Mean scores on a 4 points scale in which:

1 = not at all 2 = some 3 = much 4 = very much

* P < 0.05 ** P < 0.01

Table VI

.ttitudes toward and assessment of the importance of various aspects and components of the matriculation examinations

ASPECT OR COMPONENT	Biologists				Chemists				Physicists			
	High school N = 229		College N = 90		High school N = 19		College N = 35		High school N = 99		College N = 22	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
s interesting than other matriculation examinations			3.02	.77			2.40	.81			2.88	1.26
lects important learning objectives			2.61	.81			3.03	.93			2.39	.78
not based on memorization of facts and details			3.23	.81			2.07	.78			3.41	.67
ows for demonstrating attainment of important rnings			2.23	.81			2.00	.76			2.23	.75
PAPER AND PENCIL TEST												
tiple choice items	2.98	.81	3.00	.76	3.11	.66	2.20	.80	—	—	—	—
erpretation of graphs and tables	3.22	.66	3.49	.51	3.05	.62	3.00	.64	2.47	.82	2.74	.73
aming experiments	2.99	.82	3.21	.91	—	—	—	—	2.72	.85	3.00	.71
licting results of experiments	—	—	—	—	3.21	.63	3.19	.82	2.83	.88	2.89	.99
laining phenomena	3.30	.70	3.49	.51	3.47	.61	3.50	.62	2.47	.90	3.35	.75
ntitative calculations	—	—	—	—	1.69	.70	2.71	.71	2.71	.85	2.45	.69
litative calculations	—	—	—	—	2.00	.75	2.94	.73	3.00	.77	3.21	.63
prehension and analysis of research papers	3.30	.70	3.41	.69	—	—	—	—	—	—	—	—

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PRACTICAL EXAMINATION												
11 in using instruments	—	—	—	—	—	—	—	—	3.36	.70	2.62	.77
forming familiar experiments	2.15	.91	2.39	.91	—	—	—	—	3.36	.66	2.71	.73
forming experiments to solve unfamiliar problems	3.31	.71	3.33	.66	—	—	—	—	—	—	—	—
l examination on plants, animals and phenomena	2.65	.97	2.40	.74	2.55	.93	2.70	1.02	—	—	—	—
entifying plants or animals or ions and salts	2.35	.87	2.32	.78	2.40	.91	2.50	.71	—	—	—	—

a) Mean scores on 4 points scale in which 1 = lowest, 4 = highest. For the last 13 items the ratings pertain to the level of importance; - not included in this examination.

Table VII

Perceived impertance of different suggested changes and improvements in high school science teaching

Suggested Change	Biologists				Chemists				Physicists			
	High school N = 255		College N = 85		High school N = 57		College N = 91		High school N = 125		College N = 39	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Younger teachers	1.74	1.01	1.88	.91	1.57	.84	3.34	.78	2.20	1.02	3.33	.74
More instructional T.V	2.22	1.00	2.35	.96	2.28	1.03	2.98	.79	2.20	.92	3.00	.83
Deeper knowledge on fewer topics	2.68	1.02	2.62	.68	2.48	.95	2.95	.62	2.50	.91	2.62	.58
More hours of lab work	2.53	.91	2.68	.86	2.28	.86	2.77	.81	2.50	.89	2.19	.94
More resources: original papers, encyclopedia etc.	2.65	.91	2.88	.77	2.09	.95	2.10	.91	2.43	.96	2.14	.98
More class discussions	2.89	.79	3.00	.75	2.85	.93	2.82	.81	2.33	.84	2.86	.65
More inquiry labs	2.91	.88	2.89	.94	2.98	.71	3.02	.70	2.71	.85	3.10	.78
Improved instructionalstrategies	3.32	.82	2.92	.53	2.98	1.03	2.73	.49	3.07	.81	2.83	.46
More opportunities for thinking	3.26	.73	3.28	.80	3.29	.74	3.18	.73	2.98	.79	3.29	.60
Better coordination between lab and recitations	3.29	.73	3.31	.79	3.25	.73	3.42	.59	3.08	.78	3.24	.58
Small groups work in lab	3.30	.88	3.34	.82	3.31	.69	3.32	.78	2.97	.89	3.23	.74
Uptodate textbooks	3.46	.87	3.56	.78	3.26	.88	3.60	.72	3.31	.90	3.34	.66

Mean scores on a 4 points scale in which 1=not important, 2 = of some importance, 3 = important, 4 = very important.

Table VIII

Help of high school studies to different aspects of science studies in college [a]

Aspect	Biologists				Chemists				Physicists			
	High school N = 255		College N = 85		High school N = 57		College N = 97		High school N = 125		College N = 39	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
STUDIES IN THE LABORATORY												
Preparing lab reports	2.59	.81	1.88	.88	2.45	.83	1.96	1.00	2.47	1.08	1.68	.78
Problem solving in lab	2.77	.73	2.05	.84	2.59	.70	1.98	.93	2.18	.94	2.02	1.02
Understanding lab work	2.77	.75	2.07	.76	2.55	.79	2.13	.98	2.22	.93	2.15	1.05
Acquiring lab techniques	2.66	.78	2.08	.88	2.46	.76	1.91	1.00	2.19	.96	1.78	.83
WRITTEN MATERIALS AND LECTURES												
Learning from books and other sources	2.84	.78	2.22	.92	2.29	.70	2.01	.95	2.10	.92	2.10	.97
Understanding research	2.80	.83	2.02	.98	2.20	.87	1.84	.88	2.10	.99	1.93	1.03
Retention of material presented in lectures	2.55	.87	2.29	.91	2.56	.86	2.46	.98	2.18	.99	2.44	.98
Understanding and learning in lectures	2.89	.76	2.50	.90	2.98	.71	2.65	.86	2.35	1.01	2.51	.75

a Expectations of the high school samples and perceptions of the college samples on a 4 points scale in which 1 = very little, 2 = little, 3 = much, 4 = very much - not included in the questionnaire.

Table IX

The relationship between the nature of high school experiences and their reported help in the university

High school variable	HELP IN THE UNIVERSITY: In the Laboratory — Biologists N = 90 x	S.D.	t	Chemists N = 97 x	S.D.	t	Physicists N = 42 x	S.D.	t	In Lectures — Biologists N = 90 x	S.D.	t	Chemists N = 97 x	S.D.	t	Physicists N = 42 x	S.D.	t
Specialization:																		
university major	2.22	.71	**	2.15	.86		1.98	.85		2.50	.79	**	2.42	.68	*	2.37	.73	*
other	1.41	.46		1.84	.76		1.68	.49		1.46	.66		2.10	.80		1.85	.56	
Curriculum:																		
"old"	1.65	.71	**	1.88	.96		1.80	.87		1.96	.79		2.15	.84		2.27	.78	
"new"	2.12	.67		1.95	.75		2.82	.57		2.32	.87		2.30	.74		2.25	.55	
No. of laboratory lessons per week:																		
less than two	1.63	.48	**	1.51	.53	**	1.62	.60	**	2.10	.57	**	2.02	.78	**	1.91	.41	*
more than two	2.61	.60		2.39	.82		2.33	.79		2.74	.65		2.43	.70		2.39	.85	
Type of laboratory:																		
confirmatory	1.89	.60	**	1.96	.75	**	1.84	.70	.70	2.21	.82		2.24	.72		2.10	.73	
at least half inquiry	2.28	.79		2.50	.79		2.31	1.12	1.12	2.44	.80		2.58	.71		2.58	.81	

* $p < 0.05$ ** $p < 0.01$

Values of t and N are not reported for each analysis in order to save space

Table X

Correlations of high school related variables to self-reported knowledge and prior study in high school and achievement in college (N = 52)

High school variable	Knowledge		Prior Study		Achievement in college biology
	Concepts	Skills	Concepts	Skills	
Number of lab lessons per week	.26*	.16	.36**	.38**	
Adjusting high school biology to the university requirements	.06	.18	.19	.24*	
Maintaining continuity between high school and university	.24*	.22	.36**	.37**	
Help of high school biology to study in university labs	.49**	.48**	.41**	.36**	.25*
Help of high school biology to general study of biology at the university	.36**	.36**	.25*	.11	.22
Interest in bacteriology and in molecular biology in high school	.32**	.33**	.35**	.25*	.30*
Interest in other biological topics in high school	.44**	.40**	.35**	.19	.15

*$p < 0.05$; **$p < 0.01$

TABLE XI

Summary comparison of responses of the high school and college samples

Variable	Biology					Chemistry					Physics				
	High School N = 254		University N = 87			High School N = 57		University N = 96			High School N = 124		University N = 41		
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	t	$\bar{x}$	S.D.	$\bar{x}$	S.D.	t	$\bar{x}$	S.D.	$\bar{x}$	S.D.	t
Interest in high school topics	2.99	.45	3.21	.35	4.72**	2.76	.57	2.65	.60	1.06	2.82	.61	2.98	.57	1.45
Suggested improvement in high school	2.79	.38	2.83	.37	.88	2.73	.42	2.96	.39	3.32**	2.64	.39	2.82	.35	2.77*
Help in lab	2.70	.63	2.02	.70	8.01**	2.50	.61	1.99	.83	4.16**	2.26	.85	1.90	.75	2.33*
Help in lectures	2.77	.62	2.26	.82	5.32**	2.50	.57	2.25	.76	2.32*	2.19	.82	2.24	.73	.38
Expectations from college studies	3.04	.54	3.05	.47	.20	3.10	.49	2.99	.56	1.22	3.04	.54	2.93	.50	1.22
Suggested coordination between high school and college studies	2.95	.54	2.95	.52	.09	3.04	.61	3.03	.58	.16	2.94	.54	2.92	.64	.24
Importance of different components of the matriculation exams	2.84	.42	2.98	.43	1.21	2.73	.20	2.89	.38	1.87	2.81	.44	2.91	.48	.91

* $p > 0.05$ ** $p > 0.01$